

# MONTHLY WEATHER REVIEW

HERBERT H. KIMBALL, Acting Editor.  
CHARLES F. BROOKS, Associate Editor.

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### AEROLOGICAL INVESTIGATIONS OF THE WEATHER BUREAU DURING THE WAR.

By WILLIS RAY GREGG, Meteorologist.

#### INTRODUCTION.

Washington's advice, "In time of peace prepare for war," has never received the emphasis which his experience and prophetic vision have deserved. Fortunately, however, peace-time pursuits can often be adapted to war-time necessities, and we see overnight, as it were, the conversion of science and industry—whose only purpose *should be* to contribute to the welfare of humanity—into vast laboratories and factories, whose one purpose is to inflict as much destruction upon the enemy as human ingenuity, skill, and industry can accomplish. Thus, a nation's merchant marine becomes a fleet of transports; its steel plants a network of munition factories; and its colleges and universities a series of military camps. Again, its chemists and physicists devote their attention entirely to devising the most destructive agents possible, and its engineers to the construction of camps, pontoons, etc., and to the transportation and placement of huge engines of war.

In line with all other activities, the Weather Bureau was suddenly called upon at the beginning of the war to curtail as far as possible its usual program of furnishing advice and warnings to those engaged only in peaceful pursuits and to adapt itself to war-time conditions. Happily, many of the investigations that had been conducted by the Weather Bureau enabled it to furnish exactly the kind of information most needed by the military and naval services. Again, its trained personnel, though inadequate in numbers to take care of all the meteorological observations and investigations required at the front and in this country, nevertheless formed the nucleus around which a large organization was developed for that purpose. Thus, some of these men went directly to France and organized an extensive meteorological service there; others remained in this country and devoted their time and energy to establishing observing stations at military and naval camps; to the training of promising young men for assignment to duty as observers; and to the furnishing of data, information, and advice, whenever called for, as soon as possible and as accurately as possible. Several papers have appeared (see particularly MONTHLY WEATHER REVIEW, December, 1918) outlining the scope of these endeavors. The purpose of this sketch is to indicate briefly a few additional lines along which the Weather Bureau endeavored to "do its bit" toward the winning of the war.

#### AEROLOGICAL INVESTIGATIONS PRIOR TO THE WAR.

Prior to the war between the United States and Germany aerological investigations had been conducted by the United States Weather Bureau principally as follows:

(a) At a large number of well distributed stations during the period April to November, 1898;

(b) At Mount Weather, Va., and auxiliary stations from 1907 to 1914, inclusive; and

(c) At Drexel, near Omaha, Nebr., from 1915 to March, 1917, inclusive.

*Campaign of 1898.*—The work in 1898 consisted of "hand" kite flights to comparatively low altitudes. The data were published in detail and discussed by Prof. H. C. Frankenfield in Weather Bureau Bulletin F. One of the chief results of this campaign was the standardization of kites, meteorographs, and other apparatus through a long series of experiments by Prof. C. F. Marvin and Mr. S. A. Potter. Moreover, certain points were brought out in connection with the suitability of sites for stations with respect to proximity to centers of population, power lines, freedom from forested tracts, etc.

*Mount Weather and auxiliary stations.*—A longer-continued and more systematic series of observations was conducted at Mount Weather, Va., by means of kites and captive balloons. In addition, there were made during this period several short series of observations with sounding balloons at different points in the central and western States, viz., at Indianapolis, Ind., and Fort Omaha, Nebr., in September and October, 1909; at Fort Omaha, Nebr., in May, 1910; at Huron, S. Dak., in August and September, 1910; at Fort Omaha, Nebr., in February and March, 1911; at Avalon, Calif., in July and August, 1913, in connection with captive balloon ascensions at Lone Pine and Mount Whitney, Calif.; and at Fort Omaha, Nebr., in July and August, 1914. The data obtained at Mount Weather and its auxiliary stations were published in the bulletin of the Mount Weather Observatory and in the MONTHLY WEATHER REVIEW, together with several papers by Dr. William R. Blair and others, among the most important being "The Five-Year Summary for Mount Weather," "The Diurnal System of Convection," and "The Planetary System of Convection." Although the location of Mount Weather was far from ideal in many respects, it is not too much to say that the information derived from the observations made there and elsewhere under Dr. Blair's direction were of





FIG. 1 (B. J. S. & A. T. W.).—Beginning of a pilot-balloon run at Fort Omaha, Nebr.



FIG. 2 (B. J. S. & A. T. W.).—Making a reading at the end of the first minute, Gerstner Field, La.



incalculable value in connection with the war. Without this information the Weather Bureau would have been seriously embarrassed, if not humiliated, in its inability to furnish free-air data, and opinions based on these data, to the military and naval authorities.

*Drexel, Nebr.*—During 1914 and 1915 the work conducted at Mount Weather was transferred to Drexel, Nebr., because of the better location of the latter place with respect to storm tracks and to the needs of the forecasters. The general plan of the work at Mount Weather was continued at Drexel, but special attention was given to the diurnal variation of the several meteorological elements. Only the field work was carried on at Drexel, the computing and summarizing being done at the Central Office. Owing to the fact that the clerical force assigned to the Aerological Division was inadequate, the computing of the Drexel records was considerably in arrears, and but little information could therefore be furnished as to mean free-air conditions at that station.

*Other investigations by the Weather Bureau.*—A systematic campaign of cloud observations at Washington, D. C., in 1896–97, furnished much valuable information as to cloud altitudes and movements and therefore as to wind direction and velocity at various heights. Following the work of the *Scotia*, in 1913, a short series of kite flights on the Coast Guard cutter *Seneca* in May and June, 1915, gave some data as to free air conditions at low altitudes over the North Atlantic Ocean in the vicinity of Nova Scotia.

*Blue Hill Observatory.*—This report would be incomplete unless reference were made to the long and excellent series of observations made under the auspices of the Blue Hill Meteorological Observatory, founded and for many years maintained by the late Prof. A. Lawrence Rotch. These investigations included observations with kites at Blue Hill, near Boston, Mass.; with sounding balloons at St. Louis, Mo.; and with sounding and pilot balloons at Pittsfield, Mass. The results were published and ably discussed in different numbers of the *Annals of the Harvard College Observatory*. They have, moreover, been studied and used, to some extent, by the Aerological Division in connection with similar results obtained by the Weather Bureau.

#### PREPARING FOR WAR.

Although the work thus briefly reviewed was of great and permanent value, yet it lacked one vital and essential characteristic, viz, simultaneity of observations from a large number of well-distributed stations. Accordingly, as soon as a state of war was declared to exist between the United States and Germany, suitable action was taken for the expansion of the aerological activities of the Weather Bureau, with the result that Congress incorporated in the Army bill for the fiscal year 1917–18, an act "For the establishment and maintenance by the Weather Bureau of additional aerological stations, for observing, measuring, and investigating atmospheric phenomena in the aid of aeronautics, including salaries, travel, and other expenses in the city of Washington and elsewhere, \$100,000, to be expended under the direction of the Secretary of Agriculture."

This act did not become operative until July 1, 1917, but plans for carrying out its provisions were made as soon as the Army bill was passed, viz, May 12, 1917. Before establishing the additional stations, however, it was necessary to provide a well-trained personnel and to obtain suitable equipment. These phases of the work, together with the furnishing of data, cooperation with

the Army and Navy, establishment of special stations of a temporary nature, publications, etc., will henceforth be treated under separate heads.

#### PERSONNEL.

At the beginning of the war, as already stated, the Aerological Division comprised one field station at Drexel, Nebr., and a headquarters office at the Central Office in Washington, D. C. Ten men in all were engaged in the work—six at Drexel, with Mr. B. J. Sherry in charge, and four at Washington, with Dr. Wm. R. Blair in general charge of the entire division. In enlarging this personnel a double purpose was kept in view: (1) To train young men to conduct the work at field stations and (2) to train certain others for permanent assignment at Washington in connection with the reduction and summarizing of the data. It was decided that at least the official in charge and the first assistant at each station to be established should receive training of both kinds in order that they might become familiar with all phases of the work. This procedure served the additional purpose of enabling the Central Office force to bring the work of computing free-air records up to date. As rapidly as the men became thoroughly familiar with this work they were temporarily assigned to a field station for instruction in kite flying, kite repairing, etc., and were later permanently assigned to one of the new stations. In the meantime some of the men and several young ladies were permanently assigned to the Central Office, and not only brought the work up to date but have kept it up to date ever since. During the early part of September, 1917, Dr. Blair was commissioned a major in the Signal Corps and assigned to duty in France, and in the latter part of October, 1917, Mr. Sherry was commissioned a lieutenant in the Signal Corps and assigned to the National Research Council in connection with the organization of a military meteorological service in this country and in France.

#### EQUIPMENT.

*Kite reels.*—At the beginning of the war the division had on hand two kite reels—one at Drexel and one at the Central Office. As it was planned to establish five additional stations, action was taken to have four more of these reels constructed. These were delivered in time for use and have proved satisfactory. They are of standard type, after the design of Prof. C. F. Marvin, with some modifications by Dr. Blair. A view of one of these is shown in figure 2.

*Reel houses.*—The reel house at Drexel, Nebr., having proved satisfactory, it was decided to use this as a model, except that the size was reduced from 18 to 15 feet in diameter. These houses consist essentially of two parts—a turntable, by means of which the doorway may be presented to any desired direction, and a superstructure sufficiently large to accommodate the kite reel and accessory apparatus. Suitable turntables were procured and shipped to the respective stations, where they were mounted on concrete bases, the turntables themselves supporting the wooden superstructures. Views of the reel houses complete may be found in MONTHLY WEATHER REVIEW SUPPLEMENTS Nos. 12, 14, and 15.

*Surface instrumental equipment.*—All apparatus for recording surface meteorological conditions is of standard type, such as is used at regular Weather Bureau stations.

*Kite meteorographs.*—The meteorographs in regular use by this division are of the type designed by Prof. C. F.



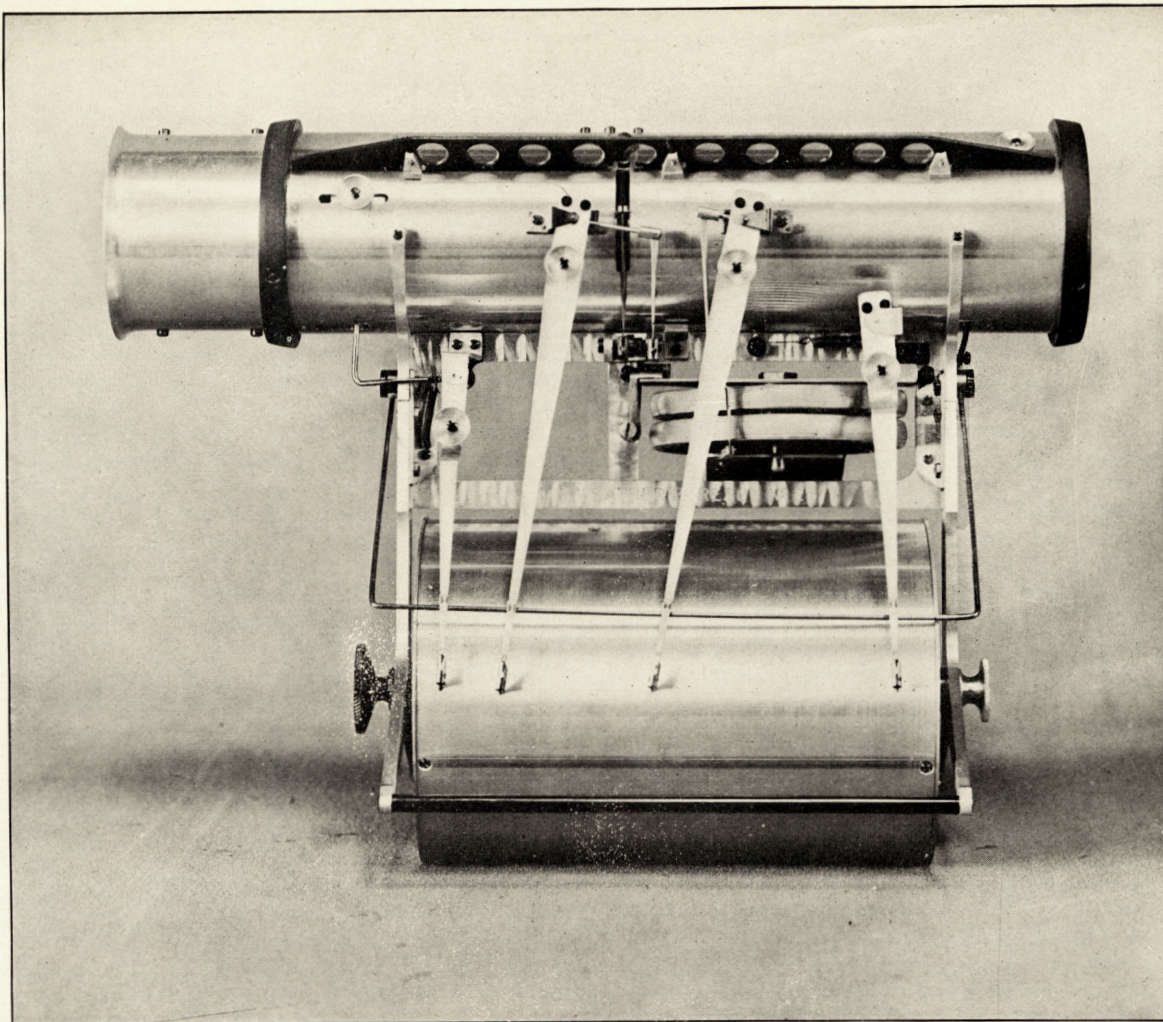


FIG. 1.—Front view of Marvin kite meteorograph in use at Weather Bureau Aerological Stations.

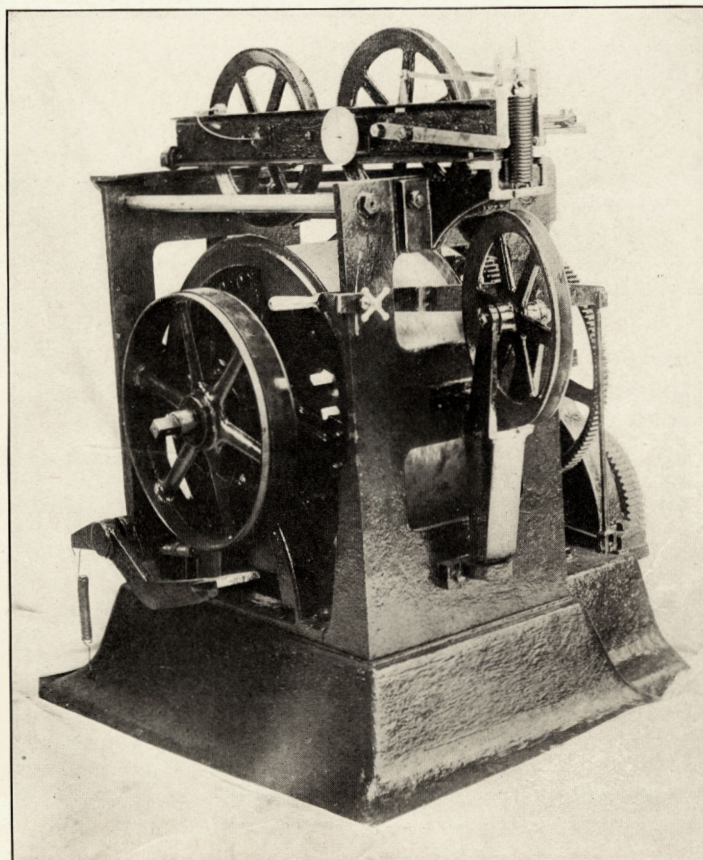


FIG. 2.—Kite reel in use at Weather Bureau Aerological Stations.

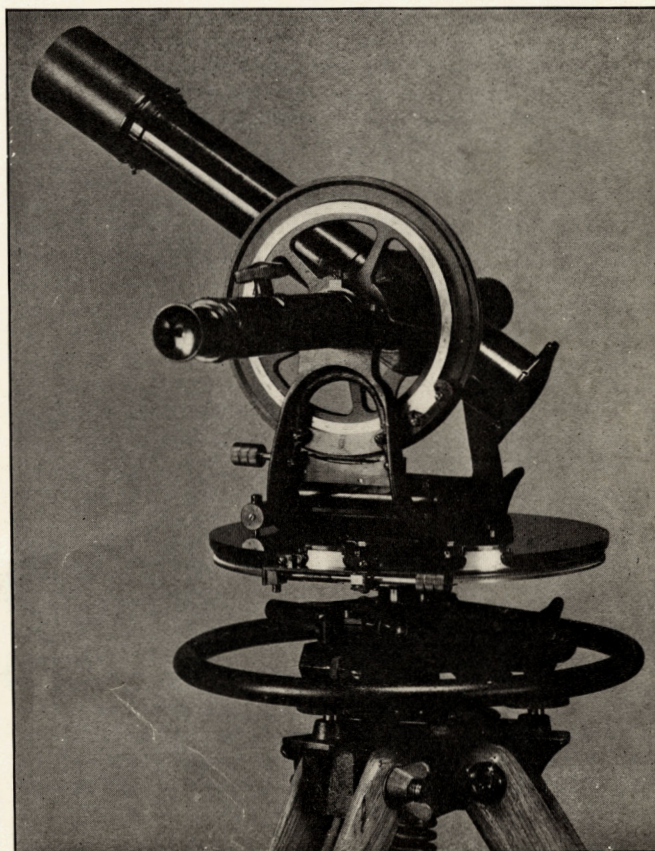


FIG. 3.—Kite and balloon theodolite in use at Weather Bureau, Military, and Naval Aerological Stations.



Marvin, with some modifications as to details of construction. These modifications are: The substitution of a "windmill" anemometer, mounted at the windward or front end of the instrument, in place of the Robinson type, separately exposed on the kite; the substitution of strips of thermostatic metal, consisting of bronze and invar plates, in place of tubes filled with ether, for the temperature element; and a different arrangement of the hairs in the hygrometer, whereby these hairs are mounted separately instead of in bundles. There were about a dozen of these meteorographs on hand and many of them were defective in one way or another. It became necessary, therefore, to repair those on hand and to procure several additional instruments. After some correspondence with instrument makers, it became apparent that the best course to pursue was to purchase the necessary materials and have the new instruments made in our own shop. Such action was accordingly taken, but even then great delay was experienced, owing to the fact that all manufacturers were pressed to the limit by war work. Delay was greatest in the case of clocks and pressure elements of these instruments. When these were finally procured, they proved to be very satisfactory, and a large number of new instruments were constructed, in addition to several old ones which had meanwhile been repaired and made ready for use. A front view of one of the new meteorographs is shown in figure 1.

*Kites.*—Each regular station needs at least 25 kites of different sizes in order that flights may be made under different conditions of wind velocity. It seemed wise to have all of these kites made at one station, in order to avoid duplication of power saws and other equipment. Accordingly, Drexel was designated a "central" station and the necessary materials for about 150 kites were sent to that station and made up into standard box kites of the Hargrave-Marvin type, such as have been regularly used by the Weather Bureau in all of its aerological investigations. By means of improvements in equipment and by concentrating on certain parts of the kites and then successively on other parts it has been possible to produce a large number in a short time, and in fact each station was supplied as soon as it was ready for them.

*Theodolites.*—The division had on hand four of these instruments, formerly in use at Mount Weather, but they had become, in general, unserviceable by reason of long use and through unavoidable accidents. Two self-recording theodolites, designed by Dr. Blair, were intended for use in sounding-balloon work. This latter type, but without the recording feature, was deemed the most satisfactory one for the kite stations and, accordingly, orders were placed for 16 of these. Only five were delivered during the war, but they were sufficient for the stations thus far established and have proved satisfactory for the purpose. In addition to these, and acting upon the recommendation of this division (aerological), the Meteorological Section of the Signal Corps placed similar orders for a large number of theodolites for use at military training fields in this country and at the front in France. A view of one of these theodolites is shown in figure 3.

*Pilot balloons.*—The use of pilot balloons was not at first contemplated by this division, it having been decided that this work should more properly be handled by the Meteorological Section of the Signal Corps. However, pending the organization of that service and in order to save time, sample pilot balloons were obtained from different companies and tested at the Central Office. On the basis of these tests orders for large

numbers of these balloons were placed by the Signal Corps, and it is understood that they have been used with success at all of the Army Meteorological Stations.

*Pressure-testing outfits.*—All meteorographs are calibrated at the Central Office before being sent out; after that they are calibrated at the stations at which they are used. For temperature and humidity the instruments are merely subjected to different conditions within a well-ventilated box or in different rooms. For wind they are suspended from a wind vane near a standard anemometer. For pressure, however, it is necessary to have special apparatus consisting of an air pump, a bell jar, and a manometer. Geryk air pumps and bell jars have been obtained from makers of scientific instruments and very satisfactory U-tube manometers, suitably mounted and graduated, have been designed and made at the Central Office of the Weather Bureau.

*Motors.*—Because of the variation in the pull of the kites on the wire and because, even when the pull is uniform, it is often desirable, for different reasons, to change the speed of reeling in, each kite station should be equipped with a variable speed motor, this variation in speed to be independent of the load to be pulled. Motors of this sort for direct current are on the market, but at some of the stations only alternating current was available. It therefore became necessary to have special motors designed and constructed—two for single-phase and two for three-phase current. After considerable delay such motors were procured and have given excellent results.

#### PERMANENT KITE STATIONS.

Five stations, in addition to the one at Drexel, were planned, and their approximate locations were indicated by Dr. Blair just prior to his departure for France. The Mount Weather and Drexel stations were situated so far from even a small town that living conditions were not conducive to that contented state of mind which is a prerequisite (more or less, depending upon individual temperament) to the attainment of harmony and the best possible results. Moreover, the cost of maintaining such a station, with its own power plant, etc., is large. In establishing these additional stations it was therefore decided, so far as possible, to select sites a short distance to the east of small towns, where electric power and living quarters for the men would be available and where the least possible difficulty would be experienced from railroads, rivers or lakes, forested tracts, human habitations, etc. Further requirements of a good kite field are that it should be level, cleared of trees, stumps, fences, etc., and have an area of approximately 40 acres. Whenever possible, it was purposed to lease land on which the owner would erect, and include in his lease, a building suitable for office, carpenter shop, and the storage of kites. After a site was selected and as soon as the lease became effective, the installation of equipment was immediately begun. As a rule, the reel house was placed near the center of the field and the buildings and surface meteorological equipment in one corner or near one side of the field. The sites selected are: Broken Arrow, Okla.; Ellendale, N. Dak.; Groesbeck, Tex.; Leesburg, Ga.; and Royal Center, Ind. Detailed descriptions of these stations may be found in MONTHLY WEATHER REVIEW SUPPLEMENTS Nos. 12, 14, and 15. See also figure 4 for their locations.

The kite work conducted at these stations has been patterned after that at Drexel and comprises daily observations, whenever possible, and, in addition, about two series of diurnal observations each month. These

latter consist of about eight or nine successive flights, from the records obtained in which it is possible to follow quite closely the diurnal changes in the various meteorological elements at different altitudes. The work at Drexel has been continued as heretofore, in spite of many changes in personnel and in addition to the instruction of new men in kite flying and to a greatly enlarged program in kite building.

#### TEMPORARY KITE STATIONS.

*Potomac Park, Washington, D. C.*—At the request of the War Department, a kite station was established at Potomac Park in January, 1918, and several flights at night were made during February and March, 1918, in connection with searchlight tests, conducted by the Engineer Corps. The kite reel was of an old type formerly in use at Mount Weather. This and other equipment were furnished by this division, the power being supplied by the Engineer Corps. During this period there were also made a few flights in connection with experiments in atmospheric electricity by the Bureau of Standards.

*Ellington Field, Tex.*—During April and May, 1918, several kite flights were made at this field for the purpose of raising devices for the detection of the approach of airplanes. A hand reel, kites, and other equipment were furnished by this division. Owing to the confidential nature of this investigation, no report of the results has been received from the Engineer Corps, but it is known that the apparatus was raised to heights of from 1,000 to 1,500 feet above the surface.

*Aberdeen, Md.*—In an endeavor to improve the range tables used by the United States Army, the Ordnance Department requested that kite flights be made at the Aberdeen Proving Grounds. Accordingly, the kite equipment formerly used at Potomac Park was installed at that place, and records were obtained with a kite meteorograph, whenever possible. This meteorograph was also used in airplane flights when conditions were unfavorable for kites.

#### PUBLICATIONS.

*Meteorology and aeronautics.*—During the First Pan-American Aeronautic Exposition at New York, February 8 to 15, 1917, it was apparent that an urgent need existed for a meteorological manual for aviators. Therefore, such a manual was prepared at the Weather Bureau, and late in the year was published by the National Advisory Committee for Aeronautics as Report No. 13. The purpose, as stated in the Introduction, was "to show the sort of atmospheric data available and to put the subject in such shape as may make it bear directly on the problems which are met in aviation." This pamphlet was given wide distribution, not only in this country but also in France, and helped to fill a long-felt want among aviators, and was used in connection with the instruction of men in the Meteorological Section of the Signal Corps.

*Mean values of free-air barometric and vapor pressures, temperatures, and densities over the United States.*—Owing to repeated calls by the Army and Navy for mean free-air data, a set of tables, giving the results of all observations made in this country by the Weather Bureau, was prepared and published in the January, 1918, number of the MONTHLY WEATHER REVIEW.

*The turning of winds with altitude.*—Soon after the publication of "Meteorology and Aeronautics" it became evident that somewhat more detailed information relative

to the behavior of free-air winds in relation to those at the surface was needed than was given in that pamphlet. Accordingly, such a paper was prepared and, likewise, published in the January, 1918, number of the MONTHLY WEATHER REVIEW. Reprints of these two papers were furnished to training fields and to various Government departments that had sought such data. Moreover, a set of "Rules" for predicting wind conditions aloft, published at the end of "The Turning of Winds with Altitude" was included in a "Manual of Aerography for the United States Navy."

*Aerological supplements.*—The policy of publishing free-air data in SUPPLEMENTS to the MONTHLY WEATHER REVIEW has been continued. At the close of the war all data up to June, 1918, inclusive, had been so published, together with some discussion and illustrations. In SUPPLEMENT No. 12 is included a brief note on "Free-Air Temperatures During the Cold Winter of 1917-18." This note endeavors to show briefly the value of free-air wind observations in predicting the direction of movement of storm areas. In SUPPLEMENT No. 13 a paper entitled "Notes on Kite Flying," by Mr. V. E. Jakl, presents useful suggestions for obtaining the best possible records under varying conditions of weather.

*Introductory meteorology.*—Early in August, 1918, the Weather Bureau was requested by the National Research Council to prepare a textbook on meteorology suitable for use in instructing men in the Students' Army Training Corps. Such a textbook was prepared under the editorial direction of Prof. W. J. Humphreys, who requested the official in charge of the Aerological Division to write Chapter III on Atmospheric Temperature and Chapter IV on Atmospheric Pressure. In the belief that a textbook for use in this Country should contain material largely drawn from this Country's sources of information, the writer of Chapters III and IV based the subjects treated principally on the results obtained at Mount Weather and auxiliary stations—Drexel, Nebr., and Blue Hill, Mass. Numerous charts and figures were included with the text, some of them new, some copied from the Mount Weather Bulletin and the MONTHLY WEATHER REVIEW, and some from Prof. Humphreys's "Physics of the Air."

*Smithsonian meteorological tables.*—In connection with a revision of these tables and at the request of Prof. H. H. Kimball, who had the work in charge, this division prepared the tables for use in computing free-air records, and for the conversion of millimeters into millibars and millibars into millimeters. Assistance was given also in the computation of gradient-wind tables.

#### SPECIAL DATA FURNISHED.

*To the Ordnance Department.*—In addition to average free-air conditions, as given in some of the publications above listed, there were frequent calls for information at specified times and places. For example, estimates of free-air densities were requested in connection with anti-aircraft and other tests at the Aberdeen Proving Grounds and the Sandy Hook Proving Grounds, when no actual records were obtainable from kites or airplanes. This division made such estimates in the following manner: By the aid of daily weather maps the days for which estimates were desired were classified with respect to the station's location in different quadrants of the HIGH or LOW which controlled the weather conditions at the times of tests. The mean temperature and humidity gradient for such conditions, as determined from five years' observations at Mount Weather, were then applied to the surface values recorded at the proving grounds. With



for our own use, it was impossible to comply at once with the British Admiralty's request. Steps were taken, however, to furnish them as soon as possible, with the result that two were sent during August, 1918, and the remaining four shortly after the close of the war.

*Italy.*—At the request of representatives of the Italian Royal Flying Corps, information was given as to the best conditions of pressure distribution under which to attempt cross-country flights between Hampton, Va., and New York; between Hampton and Chicago, Ill.; and between Chicago and New York.

#### CONCLUSIONS.

The policy of the Aerological Division was at all times to furnish as quickly as possible the available data, equipment, etc., needed by the military and naval services in the prosecution of the war, and at the same time to increase its facilities for such cooperation by making improvements in its equipment and by bringing together into concise form the results of all aerological investigations, not only in this country but in other parts of the world as well. It is believed that the most important results accomplished have been: (1) The aid rendered the Army and Navy in organizing their meteorological services; (2) the equipment furnished to those services, thus enabling them to make observations at a large number

of training fields; and (3) data, information, and advice to the military and naval services relative to free-air conditions, both as to mean values and for specified times and places. Whatever of value has been achieved is due very largely to the never-failing advice and sympathetic support of the Chief of Bureau; to the hearty cooperation of the administrative officers and chiefs of divisions of the bureau; and especially to the industry, enthusiasm, and loyalty of all the employees of this division, both at the field stations and in the Central Office.

#### AS TO THE FUTURE.

The need for aerological data in peace times will become increasingly urgent. Improvements in aircraft will very likely result in making them less dependent upon weather conditions than at present, but it is not likely that the time will ever come when a knowledge of the air cannot be used to advantage by the aviator. The development of the Aerial Mail Service and of commercial aviation makes it imperative that we continue and expand our upper-air forecasting service. Aside from these considerations free-air observations are so inherently related to surface observations that a study of them as now begun can hardly fail to increase the accuracy of "forecasting the weather."

#### SOME SCIENTIFIC ASPECTS OF THE METEOROLOGICAL WORK OF THE UNITED STATES ARMY.<sup>1</sup>

By Lieut. Col. R. A. MILLIKAN, Signal Corps, U. S. A.

There is no more interesting illustration of the application of new scientific methods to warfare than is furnished by the developments in meteorology during the Great War. Prior to 1914 a meteorological section was not considered a necessary part of the military service. No corrections had ever been made by the artillery of any army for any save surface winds. Firing by the map was almost unknown. No Sound-ranging Service, no Air Service, and no Anti-aircraft Artillery had ever existed to demand aerological data.

At the time of the signing of the armistice on the western front the Air Service and all the artillery were being furnished every two hours with the temperature, density, wind velocity, and direction, taken at the surface and at various altitudes, from 100 to 500 meters apart, up to 5,000 meters. Further, tables were prepared from which each battery could obtain the correction suited to its trajectory for the so-called ballistic wind. This is the average wind for the trajectory, weighted for the density of the air at the elevations traversed. Even machine guns when used for barrage work made use of these ballistic-wind tables.

In addition, daily forecasts were furnished to the armies in accordance with the following outline:

- A. Character of weather for each arm of the service.
- B. Winds: Surface, at 2,000 m., and at 5,000 m.
- C. Cloudiness, including fog and haze.
- D. Height of cloud.
- E. Visibility.
- F. Rain and snow.
- G. Temperature.
- H. Warning of weather conditions favorable for use of gas by enemy.
- K. Probable accuracy or odds in favor of forecast.\*

Most of the aerological data were obtained from theodolite observations on pilot balloons. The extent to which our knowledge of the upper air has been and is being extended by this pilot balloon work may be seen from the fact that before the war there existed but one station in the United States where pilot balloon explorations were regularly carried on. Within a year of the inception of the meteorological service in the United States Army, 37 complete stations for the obtaining of both surface and upper-air data in aid of aviation and the artillery had been established in the United States (see fig. 4, p. —, above) and equipped with special aircraft theodolites and pilot balloons, neither of which had ever been produced before in this country. Further, 20 such stations had been established by our forces abroad. For the manning of this service, about 500 specially selected men had been trained in this country and 314 of them sent abroad, while about 200 were held for work in the United States.

The scientific interest in this service centers about four distinct problems:

1. The extension of our knowledge of the law of motion of pilot balloons.
2. The procurement of data and the development of methods for the preparation of artillery range tables.
3. The development of long-range propaganda balloons.
4. The charting of the upper air in the United States and overseas in aid of aviation.

1. *The extension of our knowledge of the law of motion of pilot balloons.*—Prior to the development of the Meteorological Service of the Army there had been made in the United States perhaps 100 pilot balloon flights, in which the balloons had been followed by the two-theodolite method—the only method which permits of real accuracy; and in several European countries there had

<sup>1</sup> Read before the American Physical Society on Apr. 25, 1919, at Washington, D. C.  
\* A more detailed account of this work in France is being prepared for the REVIEW by one of the meteorological officers still overseas.—EDITOR.